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⑩ # CANADIAN PATENT

⑤④ PHOTOMETRIC SORTING APPARATUS

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Granted to Sphere Investments Limited, Nassau, Bahama Islands

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No. OF CLAIMS 20

This invention relates to apparatus for sorting ore and the like, and in particular it relates to apparatus which uses light reflected by the pieces of ore or other objects to obtain a plurality of parameters on which the sorting is based.

While the apparatus may be used for sorting various kinds of objects of various forms and shapes, it will be described hereinafter in connection with the sorting of ore.

10   For convenience, in the following description, the term "pieces of rock" will be considered to refer to pieces or fragments which may be undesirable or waste pieces, to pieces or fragments which may be desirable or valuable, or to pieces or fragments which contain both waste and a valuable constituent.

One type of known apparatus for sorting ore and other objects by the use of light, illuminates the objects one at a time and collects the light reflected from the object. The light is then compared

20   to a predetermined light value and if the light exceeds this value the object is accepted. If the light does not exceed this value the object is rejected.

Another type of known apparatus for sorting ore and other irregularly shaped objects feeds the objects through a sorting zone in a random stream where the objects have any random orientation but do not rest one on another. That is, the objects are in a stream one layer thick. The stream of objects is illuminated and a light detector makes repeated scans

30   across the field to detect the amount of light reflected by the surfaces of the objects in the path of the scan. The stream is divided, in effect, by a

plurality of rejection devices in abutting relationship across the stream and located downstream of the light detector. That is, each rejection device may be said to define a channel extending along the stream. If the reflected light received by the light detector for an object moving along a particular imaginary channel is less than a predetermined value, the rejection device for that channel is actuated at a time when the object is passing it. Thus, an object may be accepted or rejected according to the reflecting quality of its surface.

10   It is relatively simple to sort objects such as pieces of rock when the valuable constituent is black and the waste white, or vice versa. The sorting may be readily done on the basis of the amount or the amplitude of the reflected light. However, the variety of compositions of rock or ore is boundless. For example, a piece of rock might comprise a waste component of varying shades of grey and green, an undesired component in the form of lighter coloured flakes, and a valuable or desired component in the form of darker pebbles or small particles. It would be difficult to sort pieces of rock

20 from an ore body of this type solely on the basis of the average amount of light reflected by each piece. Indeed, it would be difficult to sort on this basis pieces of rock taken from ore bodies in many parts of the world. It would be desirable to have an ore sorting apparatus which could be adapted to sort pieces of rock taken from any one of a large number of ore bodies having a variety of different ores.

In the present invention the apparatus may be termed a photometric apparatus because it makes use of

30

amounts of reflected light. However, it does not use only the amount of reflected light as the sole basis for making a sorting decision. Rather, it derives a plurality of parameters from the reflected light and bases the sorting decision on a combination of these parameters.

Thus, the apparatus of the present invention is for sorting objects and has a means to move the objects through a sorting zone in the apparatus and means to make repeated scans across the sorting zone to detect light reflected from discrete areas of each object as the scan traverses the object. It includes means to derive from the reflected light a series of at least three parameters and means to select from the series of parameters a plurality of parameters for comparison. It includes means to compare the selected parameters in a predetermined manner and means responsive to the comparison to accept or reject a respective object.

The apparatus of the present invention derives a plurality of parameters from the detector which scans the objects and the parameters may be used singly or in different combinations where one parameter may be given more weight than another or may overrule another, depending on the particular rock being sorted. Thus, the apparatus of the present invention may derive from a scan a signal representing

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(a)   the variable amplitude of the reflected light
which is "whiter" than a predetermined value
and which may be referred to as a white linear
signal,

(b)   the amount of rock scanned where the reflected
light indicates the rock is "whiter" than a
predetermined value, which is the output of (a)
passed through a squarer circuit and which may
be referred to as a white squared signal,

10   (c)   the variable amplitude of the reflected light
which is "blacker" than a predetermined value
and which may be referred to as a black linear
signal,

(d)   the amount of rock scanned where the reflected
light indicates the rock is "blacker" than a
predetermined value, which is the output of (c)
passed through a squarer circuit and which may
be referred to as a black squared signal,

(e)   the size of the piece of rock as indicated by
20   that scan, and

(f)   the number of changes from a predetermined light
or white value to a predetermined black or dark
value, and vice versa, where the rate of change
exceeds a predetermined value, and which may be
referred to as the number of counts.

In the following description the words
"white", "whiter" and related words, and the words
"black", "blacker" and related words, are used. These
words are used for convenience to denote relatively
30   lighter and darker surfaces. In other words, a coloured
surface may be referred to as having whiter areas and
blacker areas, although the areas are not technically

white or black. Similarly, if pieces of rock are
scanned by a coloured light, for example a light from
a laser source which has only a single wavelength in
the red region, the reflected light received by the
light detector or the signal from the light detector
may be referred to as being whiter than a certain level
or blacker than a certain level.

In order that the invention may be more
readily understood, reference will be made to the
following description taken in conjunction with the
accompanying drawings, in which

Figure 1 is a side view of apparatus accord-
ing to the invention,

Figure 2 is a partial end view of the
apparatus shown in Figure 1,

Figure 3 is a simplified view of a scanning
apparatus suitable for the invention,

Figures 4 and 5 are block diagrams of
circuitry used in the apparatus of the invention, and

Figure 6 is a series of waveforms that occur
in the circuitry and are useful in explaining the
operation of the invention.

Referring now to Figures 1 and 2, there is
shown an ore sorting apparatus which sorts pieces of
rock as the pieces move in a wide path random stream
through the apparatus. The expression "wide path" as
used herein is intended to mean a path of travel having
sufficient width to permit a plurality of pieces of rock
to move along the path beside one another. The term
"random stream" as used herein is intended to mean
that the pieces of rock moving in a given direction
have a haphazard alignment and spacing.

In Figure 1 a hopper 10 is shown holding
a quantity of pieces or fragments 11 of rock. The
pieces of rock move downwards under the influence of
gravity and are deposited on a vibrating table 12 which
is suspended by springs 14 or by any other mounting
means which will permit vibration. The table 12 is
driven or vibrated by a motor 15. Vibrating table
feeders are well known in the art. The pieces of rock
move along the surface of table 12 and are discharged
at the end onto another vibrating table 16 suspended
by springs 17 and driven by motor 18. The vibrating
table 16 may have a narrow slotted portion or a
screened section to permit undersize pieces and small
particles to fall through to a disposal (not shown).
Pieces of rock are received at one end of table 16,
move along the surface, and are discharged onto a slide
plate 20.

The speeds of vibration of tables 12 and
16 are preferably each independently adjustable. The
adjustment of the two speeds permits a closely packed
but single layer of pieces to be formed towards the
discharge end of table 16. This will give an optimum
rate of sorting.

The pieces of rock fall onto slide plate 20
past a chain curtain 21 which helps prevent rocks from
rolling as they move onto slide plate 20. The pieces
of rock accelerate as they slide down plate 20 and are
discharged onto a moving belt 22. By way of example
only, a typical speed of movement of the pieces of rock
at the discharge end of table 16 might be of the order
of 40 feet per minute, while the belt speed might be of
the order of 200 feet per minute. The slide plate 20

serves to accelerate the pieces of rock to a speed
which is closer to belt speed, and the end of slide
plate 20 is curved so that it is parallel to belt
22 to deliver the pieces of rock gently onto belt 22
to minimize wear and to minimize the tendency for
the rocks to roll. Two skirts 23 on either side of
belt 22 limit the lateral placement of rock pieces
on the belt.

The endless belt 22 is supported by idlers
24 between the head roller 25 and a drive roller 26.
Roller 26 is driven by a motor (not shown). A spray
27 is positioned below belt 22 just preceding a driven
rotating brush 28 to wash and clean the belt.

As the rocks slide down plate 20 and are
deposited on belt 22 they are accelerated and this
increases the spacing between pieces of rock in the
direction of movement. This increase in spacing is
desirable for the sorting in that there is a detectable
space between one piece of rock and the next.

The pieces of rock move along on belt 22
past a scanning device 30 and are discharged in a
free fall trajectory at head roller 25 as shown in
Figures 1 and 2. The rocks pass a rejection mechanism
31 which may comprise a number of adjacent air blast
nozzles 32 arranged side by side extending across the
width of the stream of rocks. A guard plate 37
immediately above nozzles 32 is provided to protect the
nozzles from accidental damage. The guard plate 37 is
normally not touched by the pieces of rock as they pass
in free fall and provides protection against abnormal
rock position. There are 10 nozzles shown, but it will be
apparent that any number suitable to the type of rock, sorting

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rate, etc., could be used. The rejection mechanism includes a control valve for each nozzle 32 and an air source, and, when a piece of rock is to be rejected, the necessary valve is opened to direct an air blast on the piece of rock and deflect it to one side of splitter plate 33 to be carried away by belt 34. Those pieces of rock which are of sufficier. value are permitted to fall onto belt 35 for subsequent processing.

10   The rejection mechanism 31 and the zone in which scanning takes (i.e. the zone where the rocks pass scanning device 30) are separated by a distance of several feet. This separation is desirable because the air blast rejection generates some splash and mist which could interfere with the optical scanning of device 30. It may also be desirable to separate the scanning zone from the zone where rejection takes place by a baffle 36 or alternately to enclose an area with a baffle on either side of the scanning device

20   30 and provide a downward flow of clean air in the enclosed area to keep dust and mist from the optical path.

It may be desirable to have-belt 22 of a particular colour to aid in sorting. If a dark rock is being sorted it may be desirable to use a white belt to provide a contrasting background for the scanning device, and if a lighter rock is being sorted it may be desirable to use a black belt.

The scanning device 30 may be of any type

30   that will provide a continuously repeated optical scan across the stream of pieces of rock on belt 22. Many such scanning devices are known in the art. Some of

these devices make use of polarized light to avoid problems
with specular reflection. When scanning objects such as pieces
of rock, the optical scanning detector could receive specular
light reflected from small, highly polished, reflecting
surfaces and diffuse light reflected generally from other
surfaces. Specular light reflected from a given area may be
many times the value of diffuse light reflected from an area
the same size. It is the diffuse light that gives a more
precise indication of surface quality, and this could be masked

10 by specular reflection. In order to overcome this the objects
are illuminated by light polarized in a first direction, and
the reflected light going to the scanning detector is passed
through a polarizing filter polarized in a second direction at
right angles to the first direction. The apparatus of the
present invention makes use of polarized light in this manner.

In the optical scanning of objects the objects may be
placed in an illuminated area and the light detector caused to
scan across the objects to detect the diffuse reflected light.
Such a scanning system is described, for example, in British

20 Specification No. 986,177. It is, however, preferable to have
the light source scanning in conjunction with the detector as
this enables a greater illumination to be achieved in the area
of importance, that is, in the area being scanned by the light
detector. The apparatus of this invention preferably uses such
a scanning means, and a suitable one is shown in Figure 3.

Referring now to Figure 3, there is shown a light
source 40 which is preferably a laser. A laser provides a

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convenient and well defined spot of light in the scanning zone, and in addition the light is polarized. The laser beam from source 40 is directed towards a rotating eight-sided mirror drum 41 so that the rotation of drum 41 causes the light beam to travel or scan across the width of the belt. Figure 3 is not drawn to scale and is intended only to indicate one example of a suitable scanning arrangement. The belt is normally a distance from the rotating drum which is many times the drum diameter. A light detector 42, which may be any suitable photo

10   detector, is positioned to receive light reflected from the belt. The light detector 42 includes a light polarizing filter to screen out specular reflection as was previously discussed.

It will be seen that the light detector 42, in effect, scans across the belt in conjunction with the scanning of the light source 40. That is, they are both directed by the mirror drum 41 to the same spot on the belt carrying the pieces of rock, and as the drum 41 rotates this spot moves across the belt. By having both the light source 40 and the light detector 42 scan in conjunction with one another it is possible

20   to reduce the unwanted or random light to a minimum.

Figure 3 shows mirror drum 41 in two positions as an aid to understanding. One position is shown in solid lines and one in broken lines. The light path is indicated for each position. It is believed that the operation will be clear.

It is, of course, necessary to know when the scan begins at one side of the belt and when it ends at the other side. This may be done in a number of ways,

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such as, for example, by having a number of slugs of
magnetic material spaced appropriately on the sides of
mirror drum 41. Alternately, the arrangement shown in
Figure 3 may be used where a photodiode 43 is placed
at the beginning of the scan and a photodiode 44 is
placed at the end. The light from light source 40 is
reflected by mirror drum 41 onto photodiode 43 and
onto the belt at one side. As the drum 41 turns the
light sweeps across the belt, and as it reaches the

10   other side it is directed onto photodiode 44. Thus, the
outputs from photodiodes 43 and 44 may be used to define
the time of the scan, and if necessary, this may be
broken down electronically into any number of parts.

A white standard 45 is placed in the scanning
path just to one side of the limit of the belt scan.
The purpose of this is to provide a standard or refer-
ence level to stabilize the output from the light
detector 42.

Figures 4 and 5 together show the simplified

20   block diagram of the circuitry used in the invention,
and Figure 6 shows various waveforms in different parts
of the circuitry. The description will be better
understood with reference to Figures 4, 5 and 6 in
conjunction.

In Figure 4, there is shown light detector 42
which receives light reflected from the scanning mirror.
A polarizing filter is incorporated on the detector so
the light passes through it before reaching the light
sensitive element. The detector 42 provides an electri-

30   cal output representing the diffuse light reflected by
pieces of rock and the supporting belt in the sorting
zone and also diffuse light reflected by the white

standard reflector. The output from light detector 42 is
applied to a DC amplifier 50. Also in Figure 4 is shown
schematically, the two photodiodes 43 and 44 which receive
light at the beginning and end of each scan. These photodiodes
provide outputs to a timing register 51 which, in turn,
provides two output signals. Timing register 51 provides
pulses representing the timing output signals from the two
photodiodes to a gate timing circuit 52, a black clamp timing
circuit 53, and a peak white timing circuit 54. A typical

10 waveform is shown by way of example at (a) in Figure 6. Timing
register 51 also provides a number of channel outputs. That
is, timing register 51 divides the time between the start of
the scan and the end of the scan into a number of equal
portions according to the number of air blast nozzles. In the
embodiment described there are ten such nozzles, and timing
register 51 therefore divides the time of scan into ten
portions. It provides ten outputs each of which comprises a
pulse lasting for a particular one tenth of the scan. These
outputs, in effect, divide the scan into ten channels. For

20 simplicity of drawing only one such output is shown at
conductor 55. For example, a waveform which is typical of one
of the channel dividing outputs is shown at (b) in Figure 6.
The waveform at (b) represents the time period the scan is in
channel 3, and this will be discussed subsequently in
connection with Figure 5.

The gate timing circuit 52 receives the two timing
pulses from timing register 51 and provides a gating pulse
representing the actual scan time. This is used in circuits to

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be described later to gate the circuits on only for that period
of time when the scan is passing across the belt, i.e. across
the actual sorting zone. A typical waveform representing the
output of gate timing circuit 52 is shown at (c) in Figure 6.

The black clamp timing circuit 53 and the peak white
timing circuit 54 are used to stabilize the output of DC
amplifier 50. It is known that DC amplifiers tend to drift and
that some form of stabilization is desirable. The type of
stabilization indicated in Figure 4 is known and is described,
10   for example, in United States patent 3,097,744 to J.F. Hutter
et al, and will be described very briefly herein.

Considering first the peak white timing circuit 54,
this provides an output such as is shown at (d) in Figure 6 and
this output is used to gate on an automatic gain control
circuit 56 during the time the light detector is receiving
light reflected from the white standard 45. Thus, if the light
level of the scanning beam should increase for any reason, the
detector 42 will receive more reflected light and particularly
more light reflected from the white standard 45, the automatic
20   gain control circuit 56 will detect the increase in the light
reflected from standard 45 and will decrease the sensitivity of
detector 42 correspondingly.

Considering now the black clamp timing
circuit 53, this provides an output such as is shown
by the waveform at (e) in Figure 6. It will be noted
that the waveform is in the form of a square pulse

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which occurs after the scan, that is which occurs when
the light detector 42 should be receiving no reflected
light. During the time of this pulse the output from
amplifier 50 should be at a zero level or a baseline
level. Thus, the output of black clamp timing circuit
53 is applied to DC amplifier 50 and gates on a
control incorporated in the amplifier to ensure that
the output of amplifier 50 is at a baseline level
during the time of the gate.

10   The output from DC amplifier 50 is the main
output signal or the video output signal and is a signal
representing the reflected light received. It is, of
course, dependent on the pieces of rock scanned, but for
the purpose of this description the main video output
for one scan may be represented by the waveform at (f)
in Figure 6. The main video output is applied to
several circuits. One of these is an area or size
discriminator and squarer circuit 57 which also receives
a gating signal from gate timing circuit 52. The gating
20   signal ensures that the area discriminator and squarer
57 can only produce an output when the scanning beam
is sweeping the sorting zone. The discriminator is
set at a level quite close to the signal level which is
produced when the scan is on the white supporting belt,
that is, it is set at a level just darker than the
belt as is indicated at the right of the waveform
at (f) in Figure 6. The discriminator output is
squared, that is, formed into a square shaped pulse,
and the squared output is provided on conductor 58.
30   This output would be as shown at (g) in Figure 6
and represents the time periods when the scan is
on a piece of rock, or in other words, it represents

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the size of the piece of rock as seen by that scan.

The main video output and the output from the area discriminator and squarer are each applied to four circuits. These circuits are all discriminator type circuits whose levels of discrimination may be individually varied. They are gated on by the output from area discriminator and squarer 57. The four circuits are: a black discriminator 60, a white discriminator 61, a white swing discriminator and squarer 62, and a black swing discriminator and squarer 63.

The black discriminator 60 produces an output whenever the detected signal is blacker than a predetermined level. If we assume the black discriminator 60 has a discriminating level shown in Figure 6 at the right side of (f) as "black swing", then for the waveform at (f) the output of black discriminator 60 would be substantially as shown at (h) in Figure 6. The output is a linear function of the blackness of the rock and may be referred to as the black linear signal. The output of discriminator 60 is available on conductor 64 and is also applied to a squarer 65 which produces constant amplitude pulses corresponding to widths of portions of rock being scanned which are darker than the discriminator level. The output from squarer 65, for the waveform shown in Figure 6 (f), would be substantially that shown at (i) in Figure 6. This output is available on conductor 66.

Similarly the white discriminator 61 produces an output whenever the detected light has a value above a predetermined level, that is whenever

the signal is whiter than a predetermined level. It should be remembered that the discriminator 61 is gated on only when the scan is actually traversing a piece of rock. The output from discriminator 61 is a linear function of the whiteness of the rock and may be referred to as the white linear signal. This output is available on conductor 67 and is also applied to a squarer 68 which produces constant amplitude pulses corresponding to widths of portions of rock being scanned which are whiter than the discriminator level. The output from

10 squarer 68 is available on conductor 70.

Assuming the discriminator 61 is set at a level shown as "white swing" in Figure 6 (f), then the outputs from discriminator 61 and squarer 68 would be substantially as shown at (j) and (k) respectively.

The white swing discriminator and squarer 62 operates in the same manner as the combination of white discriminator 61 with squarer 68. That is, the output from white swing discriminator and squarer 62 would be of the same type as that on conductor 70. In order to keep to a minimum the number of

20 discriminator levels shown in Figure 6 (f), it has been assumed that the discriminator 61 and the discriminator portion of white swing discriminator and squarer 62 are set at the same level, i.e. at the "white swing" level of Figure 6 (f). Thus, in this particular instance, the output from white swing discriminator and squarer 62, for the same waveform of Figure 6 (f) would be substantially that on conductor 70 which is indicated in Figure 6 (k). Similarly, in this particular

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instance, the output from black swing discriminator and squarer 63 would be substantially that on conductor 66 which is indicated in Figure 6 (i).

The outputs of swing discriminators and squarers 62 and 63 are fed to variable stretch circuits 71 and 72 respectively. These stretch circuits 71 and 72 extend the pulse duration by an amount which can be set into the circuits. The outputs of stretch circuits 71 and 72 are applied as inputs to AND circuit 73. The AND circuit 73 provides an output only when there is a pulse present at both inputs. In other words, AND circuit 73 provides an output only when the main video signal swings from a black level to a white level within the stretch time, or from the same white level to the same black level within the stretch time. The rate of change from black to white, or vice versa, which will produce an output from AND circuit 73, may be altered by altering the stretch time. The output from AND circuit 73 is therefore a number of pulses representing a "count" of the times the video swings from black to white and vice versa at a rate greater than a predetermined rate.

It will be apparent that, for example, when a black piece of rock is on a white belt, there will be a count at the beginning and at the end of the scan across the rock. That is, as the scan moves across the belt it is on white or it "sees" white, and as it comes to the edge of the rock it is on black or it "sees" black. As the scan traverses the rock the video signal changes from belt white to

the black of the rock at one edge, and from the

black of the rock to belt white at the other edge.

These may both register as counts but they do not

represent changes in the reflectivity on the surface

of the piece of rock. It is, of course, desirable

to eliminate these spurious counts.

The count as the scan swings from belt

white to black presents little problem. The swing

discriminators and squarers 62 and 63 are gated by

10 area discriminator and squarer 57. Because there is

a small delay inherent in the gate signal from

discriminator and squarer 57, the white swing

discriminator and squarer 62 is not gated on at the

instant the scan passes from the belt onto the piece

of rock. Thus, there will be no count as the result

of the scan passing from belt white onto a black

rock. However, the delay in the gate signal is a

disadvantage as the scan passes from the black piece

of rock to belt white. There will be a definite

20 interval between the time when the video signal is

above the white swing level but the signal from the

area discriminator 57 has not yet cut off the

discriminator and squarers 62 and 63. Thus, as the

scan passes from the rock onto the white belt, the

AND gate 73 will receive a stretched black pulse

(from the rock) and a white pulse (as the scan just

passes onto the white belt). This will produce an

output pulse or a count from AND gate 73. The

output from AND gate 73 is fed to a gated pulse delay

30 circuit 74, which is gated by the area signal from

the area discriminator and squarer 57. The delay

in the gated pulse delay circuit 74 is adjustable

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and is set so that the count caused by the scan leaving a dark
rock and passing onto belt white occurs just after the end of
the gate signal from discriminator and squarer 57. This serves
to inhibit the count generated as the scan leaves the piece of
rock. The output of gated pulse delay circuit 74 thus
represents the number of counts as previously described and is
available on conductor 75.

For convenience in reading from Figure 4 onto
Figure 5, conductors 55, 75, 70, 67, 66, 64 and 58 have been
given terminal designations A through G respectively.

Referring now to Figure 5, it will be seen that the
signals at the terminals designated A through G are as follows:

A - a particular channel gating signal

B - the signal representing the number of counts

C - the white squared signal

D - the white linear signal

E - the black squared signal

F - the black linear signal

G - the size signal

In Figure 5 there are four switches 76, 77,
78 and 79 each of which has six positions. The
contacts for the six positions in each of the switches
76 - 79 are connected to one of the terminals designated
B-G. That is, each switch may be positioned to
select one of the six signals available at B-G. Thus,
the movable contact of each of the switches B-G will
have one of the signals on it.

So far the circuitry described has been
to provide signals representing several parameters.
The circuitry to be described below is provided for
each channel. Only the circuitry for one channel
is shown, and this may for example be for channel
3 as indicated by the waveform (b) in Figure 6
which is the signal at A. A line 85 in Figure 5
indicates where the circuitry for the individual
channels begins.

10   There are four variable gated integrators
81, 82, 83 and 84 each of which has three inputs.
One of the inputs in each integrator is connected
to A to receive the gating signal for that channel.
Another input of integrators 81-84 is respectively
connected to the movable contact of switches 76-79.
The third input is connected to a reset circuit 86.
The reset circuit 86 is connected to A to receive
a channel signal and to G to receive a size signal.
The operation of the circuits is quite straight-

20   forward. Each of the integrators 81-84 is gated on
while the scan is crossing the channel associated
with those integrators, and if there are signals
present on the movable contact of the switch 76-79
connected to that integrator, the integrator will
sum the signals. When the integrator receives a
reset signal from reset circuit 86, it provides an
output proportional to the integrated signals. The
outputs for integrators 81-84 are on conductors
87-90 respectively. The reset circuit 86 provides

30   a reset signal when the scan does not traverse a
rock for that channel. That is, reset circuit 86
provides an output or reset signal when it does not

receive a size signal from G during the time when it is gated on by the channel signal from A.

The conductors 87 and 88 are connected to a comparator 92 to provide inputs therefor, and conductors 89 and 90 are connected to a comparator 93 to provide inputs therefor. The outputs of comparators 92 and 93 are connected to a comparator 94 to provide inputs therefor. Each of the comparators 92, 93 and 94 may be set to provide an output (a) when one input is greater than the other, (b) when the ratio of one to the other exceeds or is less than a predetermined value, or (c) when the sum or difference is greater or less than a predetermined value.

The output from comparator 94 is connected to a timing and air blast control 95. When the various parameters are such that a piece of rock is to be deflected by an air blast, the signal is received from comparator 94 and the timing and air blast control circuit 95 provides a time delay sufficient for the piece of rock to reach the air blast nozzles 32 (Figure 3) and it actuates the air blast control for the nozzle in that channel to direct a blast of air at the piece of rock.

It will be apparent that more accurate timing could be obtained by providing an additional circuit which recognizes the leading edge of a piece of rock in a particular channel by the initiation of the first size signal, and which receives from reset circuit 86 a signal defining the trailing edge. If the scanning spot is well defined and the scan rapid, it is possible to determine quite accurately

the duration of the air blast that is required.

It will also be apparent that the six parameters could be used, if desired, to feed various arrangements of comparators to provide a sorting decision.

In order to provide a better understanding of the operation of the circuitry, we will consider briefly the apparatus as it might be set up for sorting one particular ore. As an example, one of the main gold bearing ores in South Africa presents some difficulty in machine sorting where the sorting

10   is based only on the average amount of light reflected. In one of the main gold bearing ores, gold is associated with certain conglomerate beds commonly referred to as "reef". This term reef describes rock having a random scatter of light coloured, roughly spherical, quartz pebbles of varying sizes embedded in a matrix of darker material. This matrix generally comprises recrystallized quartz grains, pyrite and other sulphides with other secondary constituents.

The reefs are generally narrower than minimum mining width, so a proportion of surrounding rock must be taken with

20   the reef. This proportion may be 50% or even higher. The associated waste rock is generally of two types as follows:

> (1) a dark tuffaceous lava which may be referred to
>   as "tuff", and
>
> (2) a greenish-grayish quartzite.

Speaking very generally, it is correct to say that reef has light coloured pebbles in a dark matrix, the quartzite has a fairly uniform gray or greenish colour, and the tuff has a fairly uniform blackish colour. There are, however,

30   different shades of black, white and grey in all the

rock types. In fact there is a considerable overlap in response. Light areas of the tuff and quartzite are as light as some of the pebbles, and some of the dark areas of the quartzite are as dark as some of the reef matrix. This makes it difficult to sort the ore from the waste on the basis of the amount of light reflected.

It is reasonably easy for a trained person to visually identify a piece of rock of this type as ore or waste. The eye takes in the overall appearance of the rock, and particularly the characteristic roundish section of the broken pebbles. However a sorting machine such as is known in the prior art detects the amplitude of the reflected light, and because of the variations, a consistent and satisfactory sorting decision cannot be made.

It has been found necessary to scan across a piece of rock several times and to accumulate the information received from the successive scans in order to make a satisfactory sorting decision. It has also been found necessary to derive from the light received by the light detector a plurality of parameters on which to base the sorting decision.

A study of the type of ore being used in this example indicated that a significant factor was the rapidity of change or swing from white to black, and black to white, as the scan traversed the junction of a dark matrix and a white pebble. Similar swings do occur in the quartzite rock but they are less frequent and the swing is often not as rapid. Therefore one significant sorting basis could be the number of such swings per unit area,

that is the counts per unit area. This would make a reasonable separation between reef and quartzite.

The discrimination between reef and tuff requires an additional factor. The tuff pieces frequently have small white areas which give a signal of counts per unit area greater than those derived from reef pieces. However, the tuff pieces normally have a greater percentage area of black than does the reef. A reasonable separation of reef from tuff might be made by requiring an increased number of counts per unit area if the black area per unit area exceeds a certain level.

Thus the signals required in the sorting decision would be signals proportional to

(1)   the number of counts

(2)   the area of the piece of rock

(3)   the black area of the piece of rock.

From these three signals can be derived signals proportional to

(a)   number of counts per area of rock

(b)   black area per area of rock.

These last signals are the signals on which the sorting decision for this particular rock type is to be based.

To adjust the apparatus for this the switch 76 is set to the first position to make a connection with B to select the signal proportional to the number of counts; the switch 77 is set to the sixth position to make a connection with G to select the signal proportional to area; the switch 78 is set to the fourth position to make a connection with E to select the signal proportional to the black area; the switch 79 is set to

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the sixth position to make a connection with G to select the
signal proportional to rock area. The four signals selected
are integrated as has been described. The integrated signals
proportional to counts and to rock area are applied to
comparator 92 which provides an output proportional to counts
per unit area provided that the counts per unit area are
greater than a predetermined minimum. If the minimum is not
exceeded a reject signal or a signal of a low reference value is
provided as an output. If this minimum is exceeded the output
signal proportional to counts per unit area is applied to
comparator 94, and this is a tentative accept signal.

The integrated signals proportional to the black area
and to the rock area are applied to comparator 93. If the
ratio of black area to total rock area is less than a
predetermined value a no reject signal or a signal of a low
reference value is provided as an output. If the ratio of
black area to total rock area is greater than this value a
tentative reject signal comprising the ratio of black area to
rock area is provided. This output is applied to comparator
94.

Comparator 94 receives the two signals as
described. If the ratio of these signals is greater
than a predetermined value, the piece of rock should
be accepted. If the ratio of these signals is less
than this predetermined value the piece of rock
should be rejected, and an appropriate output signal
is provided to cause rejection. This will perhaps
be made clearer by reference to the following table:

COMPARATOR 92

Inputs	Decision	Outputs
Counts and Tot.area	Accept: $\dfrac{\text{Counts}}{\text{Tot.area}} > x$	Tentative accept: $\dfrac{\text{Counts}}{\text{Tot.area}}$
	Reject: $\dfrac{\text{Counts}}{\text{Tot.area}} < x$	Reject: Low ref. signal

COMPARATOR 93

Black area and Total area	Accept: $\dfrac{\text{Black area}}{\text{Tot.area}} < y$	Accept: Low ref. signal
	Reject: $\dfrac{\text{Black area}}{\text{Tot.area}} > y$	Tentative reject: $\dfrac{\text{Black area}}{\text{Tot.area}}$

COMPARATOR 94

From Comparators 92 & 93	Accept: $\dfrac{\text{Sig.from comp.92}}{\text{Sig.from comp.93}} > z$	Accept: No signal
	Reject: $\dfrac{\text{Sig.from comp.92}}{\text{Sig.from comp.93}} < z$	Reject: Signal to rejection mechanism

The symbols x, y and z in the above table are
predetermined levels chosen experimentally for the
particular rock.

It will be seen that comparator 94 could
receive four possible inputs as follows:

(1) tentative accept from comparator 92
     accept from comparator 93

(2) tentative accept from comparator 92
     tentative reject from comparator 93

(3) reject from comparator 92
     accept from comparator 93

(4) reject from comparator 92
     tentative reject from comparator 93

It will be apparent that in (1) above the
piece of rock will be accepted as the ratio will be

high because of the low reference signal from comparator 93. In (2) above it will depend on the actual ratio whether or not the piece of rock is accepted or rejected. In (3) above, there will be two low reference signals, and in this instance these signals are selected so that the signal from comparator 92 is over-riding; that is, the signals are selected so that the ratio required by. comparator 94 for acceptance will not be met. In (4) above, there will be a reject output because the ratio will be small due to the low reference signal from comparator 92.

The preceding example will help to show the versatility of the apparatus. The apparatus is able to sort a very great number of types of ore from various parts of the world. It is necessary only to study the ore, select suitable parameters for that ore, and decide on the over-riding factors where necessary.

It will, of course, be apparent that the apparatus is able to sort irregularly shaped objects other than pieces of rock by scanning the objects and developing from the reflected scan a plurality of parameters on which the sorting of the objects may be based.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1.   Apparatus for sorting objects comprising

means to move the objects through a sorting zone in the apparatus,

scanning means to make repeated scans across the sorting zone to detect light reflected from discrete areas of each object as the scan traverses the object,

means to derive a series of at least three parameters from the reflected light,

selecting means to select from said series of parameters a plurality of parameters for comparison,

comparator means to compare the selected parameters in a predetermined manner, and

rejection means responsive to the comparison to reject an object.

2.   Apparatus as defined in claim 1 and further including

integrator means for each selected parameter to integrate the value of the respective selected parameter from successive scans across an object or across a predetermined portion of an object.

3.   Apparatus as defined in claim 1 in which said plurality of parameters is at least three parameters.

4.   Apparatus for sorting pieces of rock having ore and waste comprising

means to move pieces of rock through a sorting zone in the apparatus,

scanning means to make repeated scans across the sorting zone including a light detector to detect light reflected from discrete areas of each piece of rock as the

scan traverses its surface and to provide an electrical

output representing reflected light,

circuit means receiving said electrical output

and deriving therefrom a series of at least three parameters,

selecting means connected with said circuit

means to select from said series of parameters a plurality of

parameters for comparison,

comparator means connected with said selecting

means to receive said plurality of parameters, to compare

said plurality of parameters in a predetermined manner and

to provide a sorting signal based on the comparison, and

rejection means connected with said comparator

means and responsive to said sorting signal of a predeter-

mined value to reject a respective piece of rock.

5.   Apparatus as defined in claim 4 in which said se-

lecting means selects at least three parameters as said

plurality of parameters for comparison.

6.   Apparatus as defined in claim 4 in which said

selecting means selects as said plurality of parameters for

comparison at least three of the following parameters

       (a)   a white linear signal which is a variable

             amplitude signal representing reflected light

             which is whiter than a predetermined level,

       (b)   a white squared signal which is of substanti-

             ally constant amplitude and of a pulse

             duration corresponding to the time the

             reflected light is whiter than a predeter-

             mined level,

       (c)   a black linear signal which is a variable

             amplitude signal representing reflected light

             which is blacker than a predetermined level,

       (d)   a black squared signal which is of sub-

             stantially constant amplitude and of a pulse

duration corresponding to the time the reflected light is blacker than a predetermined level,

(e) a size signal representing the size where traversed by the scan, and

(f) a signal representing the number of counts where a count is a change from a predetermined white level to a predetermined black level, and vice versa, with the rate of change in excess of a predetermined rate of change.

7. Apparatus as defined in claim 6 and further including integrator means for each selected parameter connected between said selecting means and said comparator means to integrate the value of the respective selected parameter from successive scans across a piece of rock or across a predetermined portion thereof.

8. Apparatus as defined in claim 7 in which said comparator means comprises a plurality of comparators each having two inputs and an output, one of said comparators being adapted to provide at its output said sorting signal and being adapted to receive at at least one of its inputs the output from another comparator, said parameters constituting at least one of the inputs to at least two comparators.

9. Apparatus as defined in claim 7 in which said selecting means selects as said plurality of parameters for comparison a first, second and third parameter, and in which said comparator means comprises a first, second and third comparator each having two inputs and an output,

said first comparator being connected to said selecting means to receive at its two inputs said first and second input parameter signals and to provide at its output

a first output signal which is related to a comparison of
the two input signals,

said second comparator being connected to said
selecting means to receive at its two inputs said second and
third input parameter signals and to provide at its output
a second output signal which is related to a comparison of
the two input signals,

said third comparator having its two inputs con-
nected to the output of said first and second one of said
comparators to receive said first and second output signal
and to provide at its output said sorting signal which is
related to a comparison of said first and second output signals.

10.   Apparatus as defined in claim 8 or 9 in which at
least one comparator is arranged to provide an output
signal indicative of a signal at one of its inputs being
greater than a signal at the other of its inputs.

11.   Apparatus as defined in claim 8 or 9 in which at
least one comparator is arranged to provide an output signal
indicative of the ratio of the signal at one of its inputs
to the signal at the other of its inputs lying outside a
predetermined range of values.

12.   Apparatus as defined in claim 8 or 9 in which at
least one comparator is arranged to provide an output signal
indicative of the sum or difference of the signals at its
inputs lying outside a predetermined range of values.

13.   Apparatus for sorting pieces of rock having waste
and a valuable constituent, comprising
        a wide path handling means to move pieces of rock
in a wide path random stream through a sorting zone along a
predetermined path,
        said path having a plurality of imaginary parallel

channels,

scanning means including a light detector to make repeated scans across said path in said sorting zone to detect light reflected from discrete areas of each piece of rock as the scan traverses its surface and to provide a main video output signal representing the reflected light,

electronic means associated with said scanning means to provide a timing signal indicative of the scan passing the boundaries of said imaginary channels,

circuit means connected with said scanning means to receive said main video output signal and to derive therefrom a series of at least three parameters,

selecting means connected with said circuit means to select from said series of parameters a plurality of parameters for comparison,

comparator means connected with said selecting means and said electronic means to receive from said selecting means said plurality of parameters, to compare said plurality of parameters in a predetermined manner and to provide a sorting signal based on said comparison and related to the position of a piece rock with respect to said imaginary channels,

a plurality of rejection devices, one for each of said imaginary channels, in side by side abutting relationship corresponding to said channels and extending across the width of said path,

said rejection devices being positioned so that pieces of rock pass said rejection devices after passing said scanning means,

said rejection devices being responsive to a sorting signal of a predetermined value for a respective channel to reject a piece of rock from which said sorting signal was developed.

14.   Apparatus as defined in claim 13 in which said selecting means selects as said plurality of parameters for comparison at least three of the following parameters:

(a) a white linear signal which is a variable amplitude signal representing reflected light which is whiter than a predetermined level,

(b) a white squared signal which is of substantially constant amplitude and of a pulse duration corresponding to the time the reflected light is whiter than a predetermined level,

(c) a black linear signal which is a variable amplitude signal representing reflected light which is blacker than a predetermined level,

(d) a black squared signal which is of substantially constant amplitude and of a pulse duration corresponding to the time the reflected light is blacker than a predetermined level,

(e) a size signal representing the size where traversed by the scan, and

(f) a signal representing the number of counts where a count is a change from a predetermined white level to a predetermined black level, and vice versa, with the rate of change in excess of a predetermined rate of change.

15.   Apparatus as defined in claim 14 and further including integrator means for each selected parameter connected to said selecting means to integrate the value of the respective selected parameter for successive scans across

a piece of rock or predetermined portion thereof.

16.   Apparatus as defined in claim 14 in which said wide path handling means comprises

        a hopper,

        at least one vibrating table for receiving pieces of rock from said hopper and delivering from the end thereof a wide path random stream onto the upper surface of an inclined slide plate, and

        a moving belt arranged to receive the wide path random stream of pieces of rock from the slide plate, carry said pieces of rock past said scanning means and discharge said pieces of rock past said rejection devices.

17.   Apparatus as defined in claim 14 in which said scanning means comprises

        a laser light source directed onto a rotating, multi-surfaced mirror to cause a spot of light to traverse the sorting zone, said light detector being arranged to receive diffuse light from said mirror reflected onto said mirror from pieces of rock in said spot of light.

18.   Apparatus as defined in claim 14 in which said selecting means is switch means operable manually to select desired ones of said series of parameters.

19.   Apparatus as defined in claim 14 in which said rejection devices each comprise an air blast nozzle and a source of air under pressure connected to said nozzle, and an air blast control valve to control the flow of air to said nozzle according to said sorting signal.

20.   A method for sorting irregularly shaped objects comprising the steps of

        moving the objects through a sorting zone,

        making repeated scans across the surface of each

object to detect light reflected from its surface,

providing from said detected light an electrical output signal varying in accordance with the detected light,

deriving a series of at least three parameters from said electrical output signal,

selecting from said series of parameters a plurality of parameters and integrating the value of each selected parameter for a particular object or portion thereof,

comparing the integrated values of the selected parameters in a predetermined manner,

providing a decision signal based on the comparison representing a sorting decision, and

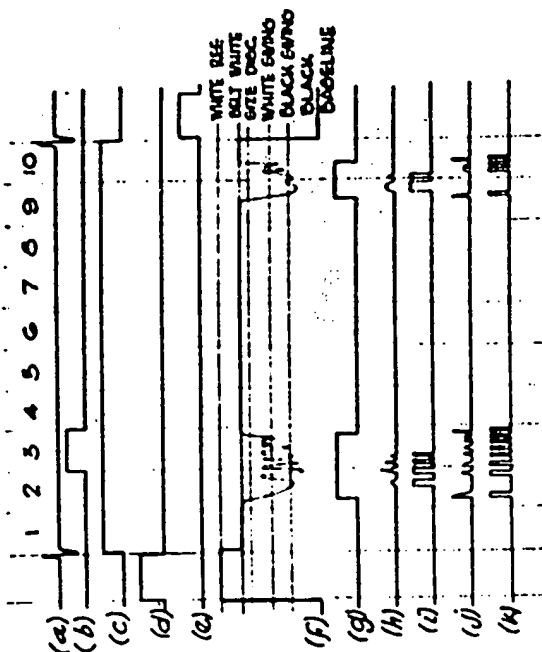directing each object along one of two paths in accordance with the decision signal.
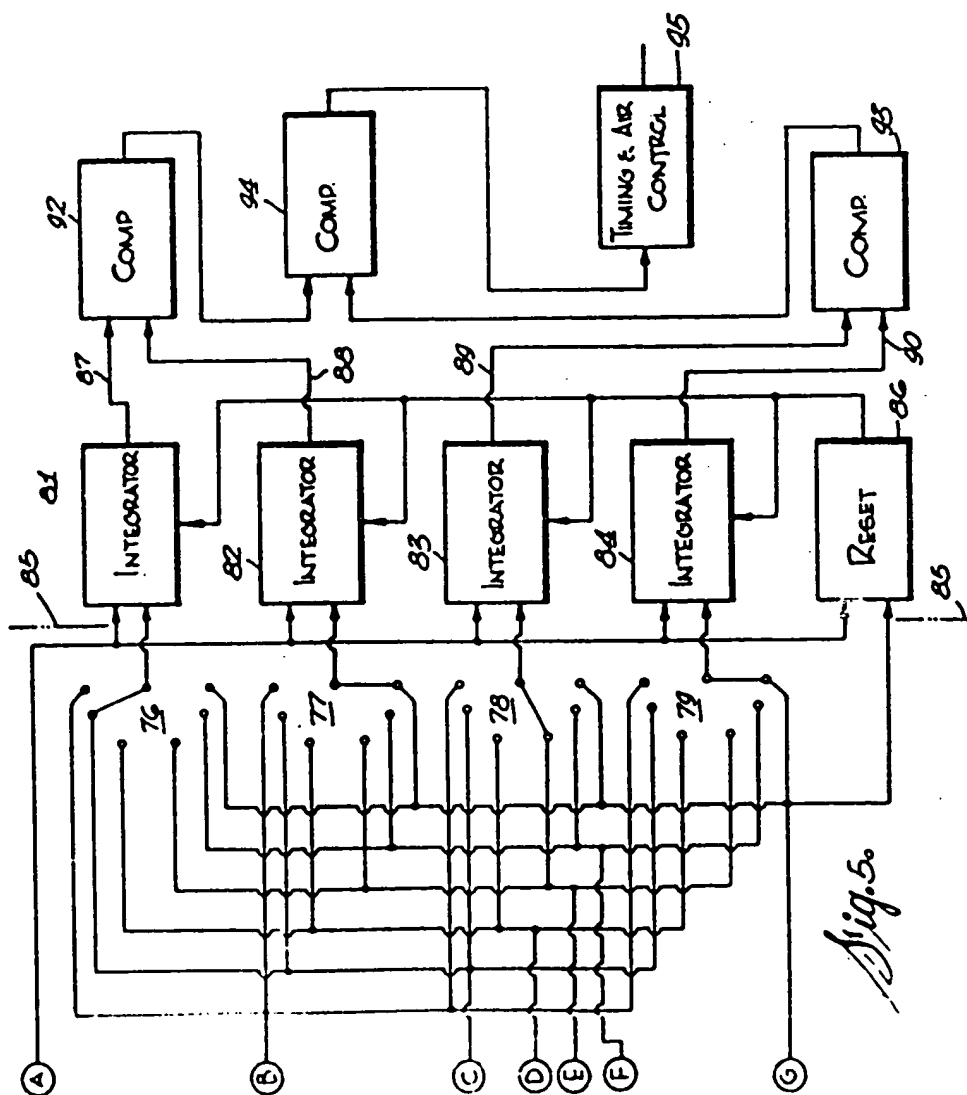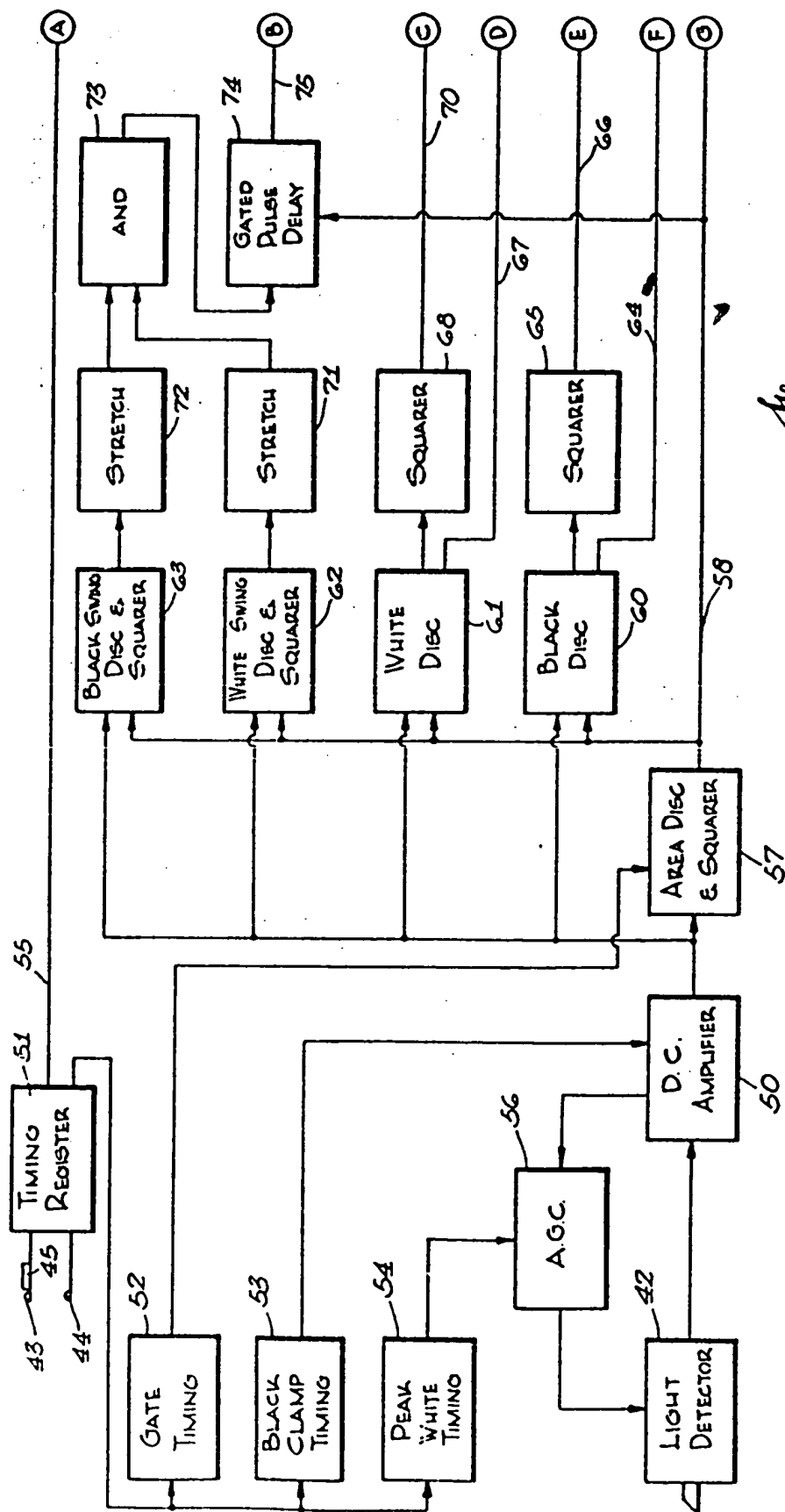
Fig. 6

Fig. 5.

Fig. 4.

Fig. 2.

Fig. 3.

Fig. 1.